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A MACHINE FOR CUTTING A SEED POTATO INTO SIX PIECES OF UNIFORM SIZE AND SHAPE

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INTRODUCTION

The range of sizes of potatoes used for seed purposes requires cutting into varying numbers of seed pieces, depending upon the size of the tuber. The number and characteristic distribution of eyes varies between different varieties of potato, but within a variety the number and distribution are independent of the size of a tuber. That is, a large tuber of a certain variety has no more eyes than a small one of the same variety. Consequently, when seed pieces are cut without regard to the location of the eyes, it is necessary to limit the number of pieces into which the tubers are cut so as to avoid an excessive number of pieces without eyes. All mechanical cutters, including this experimental one, disregard the distribution of eyes. In most operations where the seed cutting is done by hand this is also true.

Mechanical seed potato cutters currently in use may be classified as follows:

A. Automatic machines

1. Sizer-cutters for cutting round varieties into 2, 3, or 4 pieces.
2. "B" splitters for cutting small tubers into two pieces.

B. Nonautomatic (hand-fed) machines for cutting both round and long varieties into 2, 3, 4, 6, or 8 pieces.

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Machines designated as "automatic" do not require hand positioning of the tubers in the machine. The "nonautomatic" machines require individual positioning of the tubers by the operator. In one type the number of pieces into which the tuber is cut is determined by the operator's positioning of the tuber. In another type the tubers are individually fed into the machine by the operator, but the selection of the number of pieces into which a tuber will be cut, is gaged automatically by the machine according to its length.

Tests were made with Red Pontiac potatoes, selected by weight to produce seed pieces averaging about 1-1/2 ounces in weight. When cut into four or a fewer number of pieces 100 percent of the pieces will have one or more good eyes. When cut into six pieces, 94 to 95 percent will have at least one good eye. When cut into eight pieces, 75 to 82 percent of the pieces will have eyes.[2/] (Varieties with fewer eyes than Red Pontiac will produce an even lower proportion of good seed pieces when cut into six or eight pieces.) The maximum size of Red Pontiac Tubers to be used for seed purposes should be limited to the size that is suitable for cutting into six seed pieces. In the case of varieties with fewer eyes than Red Pontiac, it may be advisable not to exceed the size suitable for four seed pieces.

Presizing of the tubers can increase efficiency in the use of seed potato cutters. The use of presized seed stock can eliminate the requirement of extra labor for hand cutting the oversize tubers rejected by the automatic machines.

The quality of mechanically cut seed pieces, when evaluated in respect to the size variation and incidence of seed pieces without eyes, has been found to be equal to most hand cut seed.[2/] Limiting the maximum size of large potatoes used in machines to that which is economically suitable for six seed pieces will improve the quality of the seed by reducing the proportion of blank seed pieces. Analyses of the capabilities of currently available seed potato cutters, the characteristics of seed potatoes and the advantages of presizing of seed potatoes indicated a need for a machine designed especially for cutting tubers of from approximately 7 to 13 ounces into six pieces. The machine herein described was designed to accomplish this in accord with the requirements that it (1) cut long or round varieties of seed potatoes, (2) produce seed pieces of uniform size and shape from individual tubers, (3) produce seed pieces of a desirable blocky shape with a minimum of cut surface, and (4) cut presized seed stock within a specified size range with a minimum of labor and a maximum of economy.

2/ French, G. W., Mechanical Cutting and Handling of Seed Potatoes. U. S. Department of Agriculture, ARS 42-21, January 1959.

Commercial automatic seed potato cutters have greater capacity than this experimental machine but this machine performs a function that cannot be accomplished with any commercial automatic seed potato cutter. This machine was designed primarily to reduce the cost of cutting the large seed potatoes. Mechanical seed potato cutting can be more efficiently accomplished if presized potatoes are used.[2/] With this machine the size class for six seed pieces can be cut at a rate equal to that of four or five workers cutting potatoes by hand.

The six-piece cutting machine was built for experimental purposes; subsequent testing demonstrated that it met the above requirements in a satisfactory manner. The machine was designed to test certain principles and is not regarded as a unit to be precisely duplicated in a commercial unit for volume production. A manufacturer would find it desirable to make some modifications, such as the use of some castings, to reduce production costs. In view of this it is believed that dimensioned drawings of all the parts would have a very limited value. The objective of this publication is, therefore, to describe the functional principles and the capabilities of the experimental machine.

FUNCTION OF THE EXPERIMENTAL MACHINE

The experimental machine (Fig. 1) was designed for hand-fed operation to cut 7- to 13-ounce potatoes into six pieces of uniform size and shape. The shape of the seed pieces can be understood by visualizing a tuber cut, into two equal parts in a plane perpendicular to its long axis, and then each half cut in three radial planes. Figure 2 illustrates the uniformity in size and shape of the seed pieces from individual tubers, as produced from two tubers differing considerably in size.

Figure 1. Experimental self-equalizing seed potato cutter.

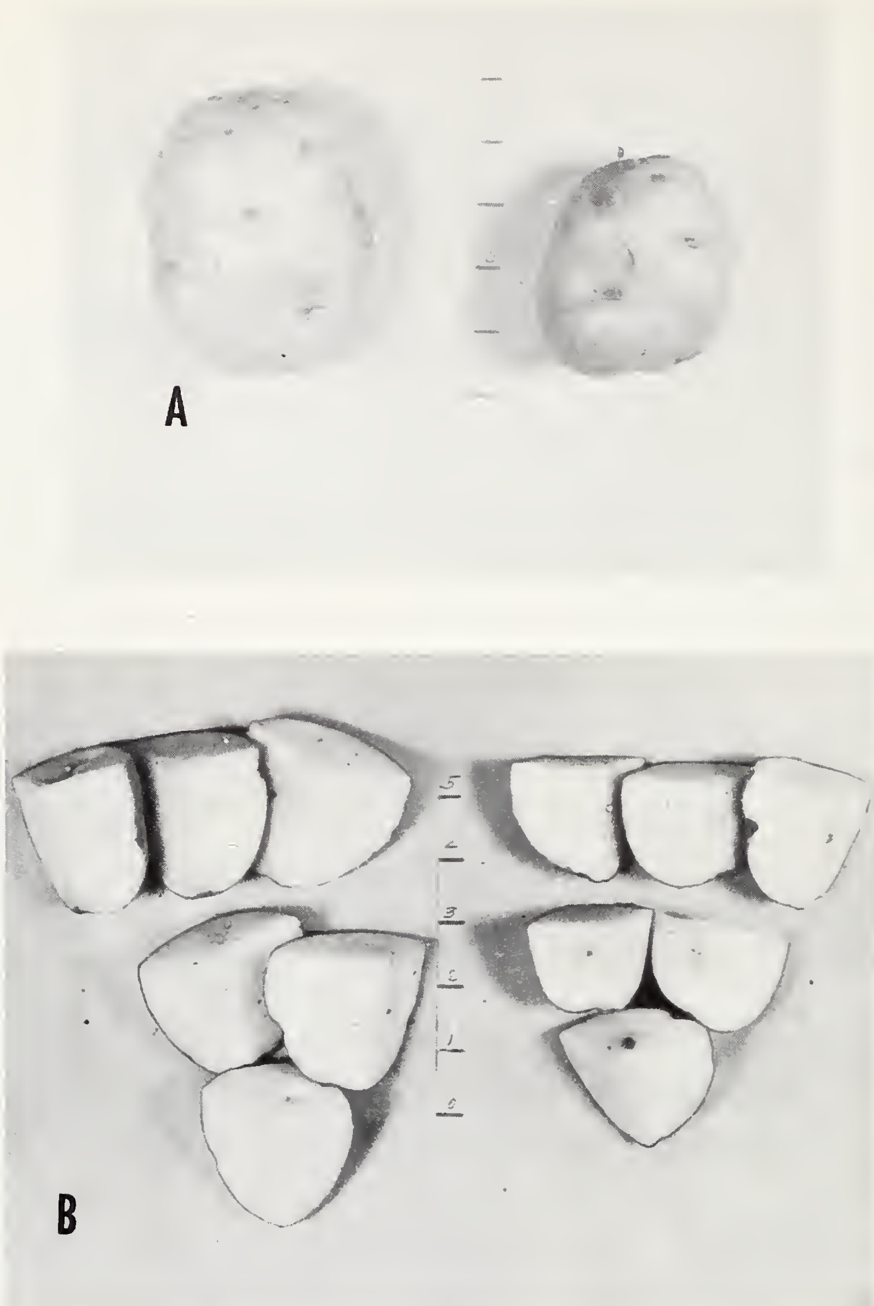

Figure 2. Red Pontiac potatoes: A, before cutting (larger tuber weighed 14 ounces, the smaller one 8 ounces); B, seed pieces produced when the tubers shown in A were cut with the experimental seed potato cutter.

FUNCTIONAL ELEMENTS

The use of photographs should help in providing an understanding of the functional components of this seed potato cutter. Because it is virtually impossible to clearly show all these elements in a single photograph taken from one position, the machine was photographed from several positions. As an aid to relating the parts shown in the several photographs, a systematic designation of certain parts by letters is employed. The parts so designated are five rotating shafts. (See Fig. 6, on p. 8.) Shafts A and C are driven from the output shaft of a speed reducer. The sprockets on shafts A and C have the same number of teeth. Shaft B is driven from shaft A through a pair of miter gears with a 1 to 1 ratio. Shafts A, B, and C, consequently, rotate continuously, at a constant speed. Shafts D and E rotate intermittently.

Rotating Table

Four sets of three-bladed knives for vertical cutting and the tuber centering units above them are mounted on a table (fig. 3) that rotates intermittently a quarter of a revolution for each cycle of the cutting

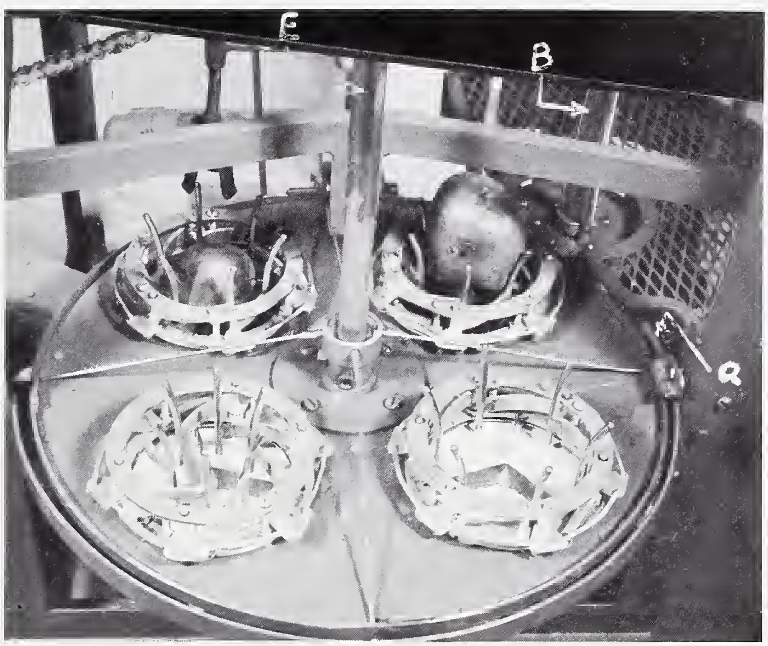

Figure 3. Rotating table with four sets of 3-blade knives and tuber positioning-holding units. The curved upright rods of the unit on the front right side are wedged completely open in order to show the three-bladed knife that cuts a pushed tuber longitudinally in 3 planes. A friction brake (a) is controlled by mechanism shown in figure 5.

mechanisms. The time interval between the completion of one quarter turn and the beginning of the next quarter turn is 33-1/3 percent greater than the time that the table is in motion in making the quarter turn. During the interval that the table is not moving, two tubers are in process of being cut and two tubers are placed by the operator in the empty tuber centering units. The mechanism for producing the intermittent rotation of the table is shown in figure 5, p. 7.

A crank on shaft B actuates a ratchet-mechanism on shaft E, about which the ratchet arm oscillates. The ratchet disk and the rotating table are fixed on shaft E. Below the ratchet disk is a large disk with semicircular cutout notches into which a roller, mounted on a spring-loaded arm, is drawn to insure that the table remains in a fixed position while the plungers are descending. At the same time that the roller is

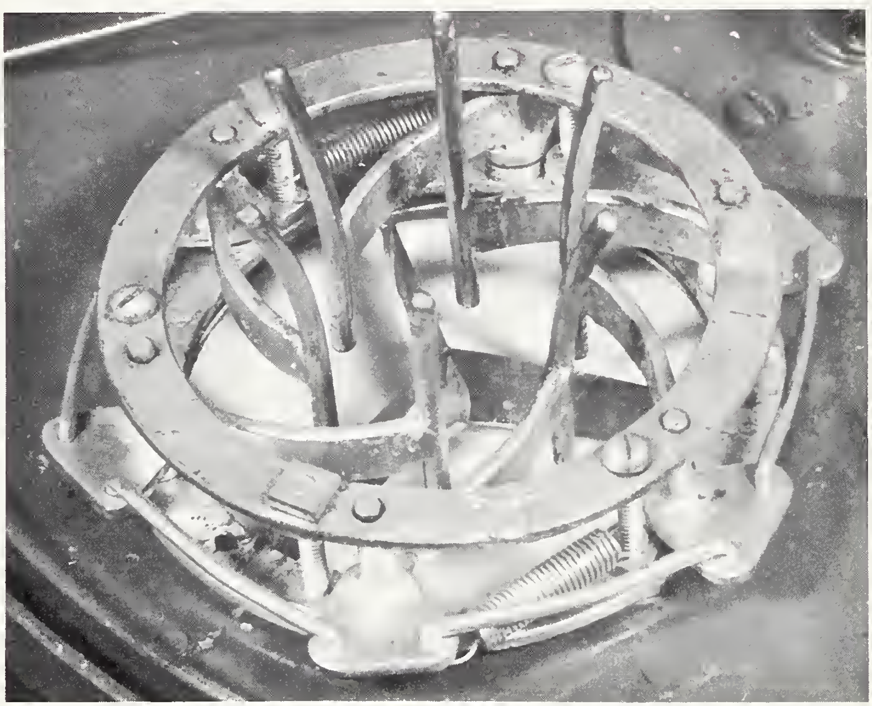

Figure 4. Enlarged view of the front left tuber positioning-holding unit in figure 3. The linkage is such that the curved rods are always the same distance from the junction of the 3 blades. A potato pushed downward into the unit forces the rods apart against the resistance of two tension springs.

drawn into the notch on the lower disk, the spring that accomplishes this applies force to a brake that acts on the rim of the table to bring about a smooth stop to the rotation (Fig. 3). The roller is disengaged from the notch, and the brake is disengaged with the reverse oscillation of the ratchet arm.

The design of the table combines light weight with adequate strength in order to minimize the inertial forces associated with starting and stopping the rotation of the table. Bicycle spokes are used to provide strength to resist the force applied to the table by the downward thrust of plungers in pushing the potatoes through the three-bladed knives.

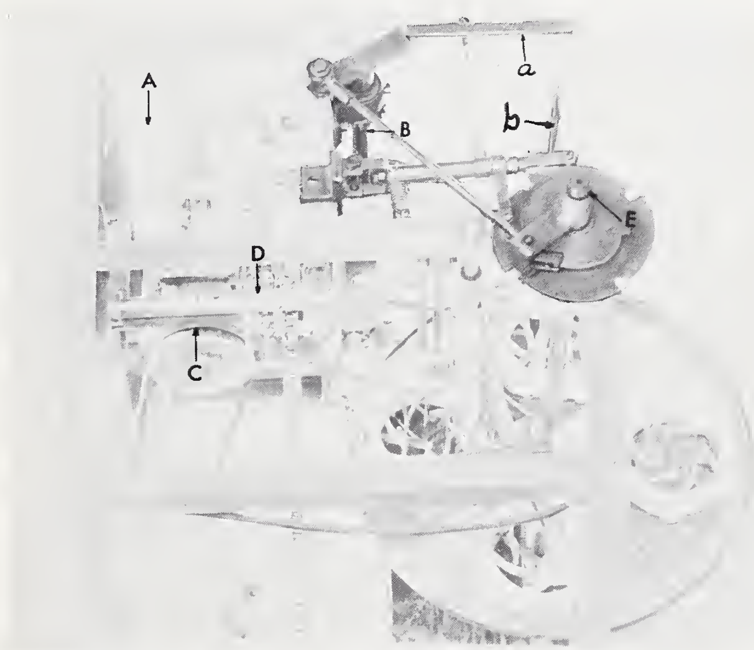

Figure 5. Mechanism for producing intermittent rotation of table, which is fixed on shaft E. The table is rotated 90° with each revolution of shaft B. As the roller on the pivoted arm drops into a notch on the lower disk fixed on the upper end of shaft E, torque is applied through a lever (a) to a rod (b); this rod transmits the force to a friction brake that acts upon the rim of the table. (See also Fig. 11.) The rotation of the table is stopped very smoothly by means of this brake.

Plungers for Pushing Tubers Through Knives Mounted on the Table

Two plungers, rigidly mounted on the same reciprocating bracket operate together to push tubers onto two adjacent knives. The first plunger pushes the tuber downward upon, but not entirely through, the set of three knife blades, to make cuts on three intersecting planes. The line of intersection coincides with the long axis of the tuber. Simultaneously, the second plunger pushes the preceding tuber, which moved into position with the last 90° rotation of the table, the rest of the way through the knife blades.

The plungers are in motion one-half of the time. They remain at the bottom of their stroke for the interval during which the transverse cut is made. They are ascending when the table starts to rotate. (See Fig. 12, on p.13.) The period in which the plungers are stationary at the bottom of the stroke is shorter than the stationary period at the top of the stroke. This provision is necessary to prevent interference with rotation of the table. Figures 7 and 8 show the mechanism for producing the intermittent action of the plungers. The crank on shaft D imparts reciprocating motion through a connecting rod to the bracket on which the two plungers are attached. The crank throw is 2-1/4 inches. In figure 6 the plungers are at the top of the stroke, in 8 and 10 at the bottom. Shaft D, when in motion, is driven through an intermittent gear on shaft C. Shaft C turns at a constant speed and shaft D, when in motion, has an angular velocity two times that of shaft C. Shafts A, B, C, and D turn 360° per cycle.

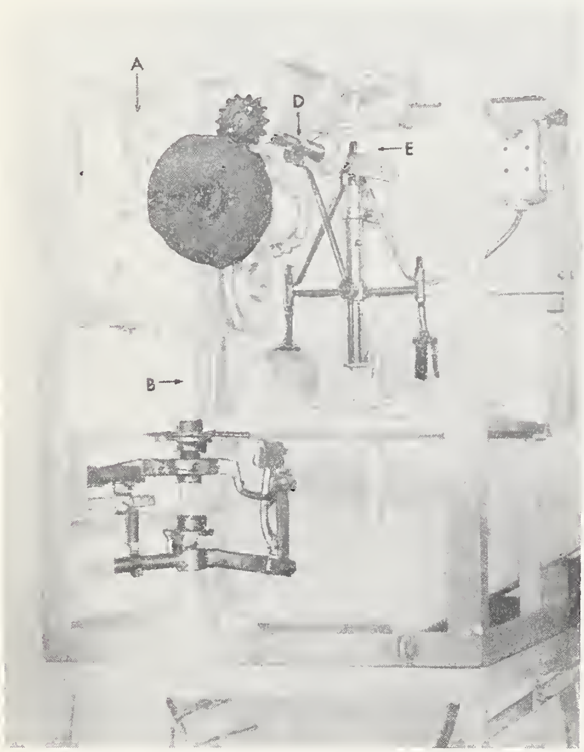

Figure 6. The reciprocating plungers are descending; the circular metal pad on the end of the plunger has reached the upper end of a tuber. (See also Fig. 7.)

The gear on shaft D is made with a 14-tooth No. 40 roller chain sprocket. The intermittent gear on shaft C is constructed with two sections of No. 40 roller chain riveted to a plate through holes one-half inch apart located on the two arcs of a circle, the radii of which are equal to the pitch diameter of the 14-tooth sprocket on shaft C. When the plungers stop at the top or the bottom of the stroke, one of the concave sections of the hub projection on the driven sprocket on shaft D is concentric with a matching section in the flange of the intermittent gear on shaft C (Fig. 8).

Figure 7. The reciprocating plungers have descended further and the tuber has been pushed downward until the lower end has just contacted the pad on the gaging mechanism. When the plunger reaches the lowest position of the stroke, a gaging pad will be depressed and a rotating knife will be lowered from its topmost position, as can be noted in figures 10 and 11. The driving sector of the intermittent gear on shaft C engages the driven sprocket on shaft D which rotates at twice the angular velocity of shaft C.

Thus, shaft D is prevented from accidentally turning during the phase of the cycle when the plungers are required to remain stationary. (See Fig. 6.)

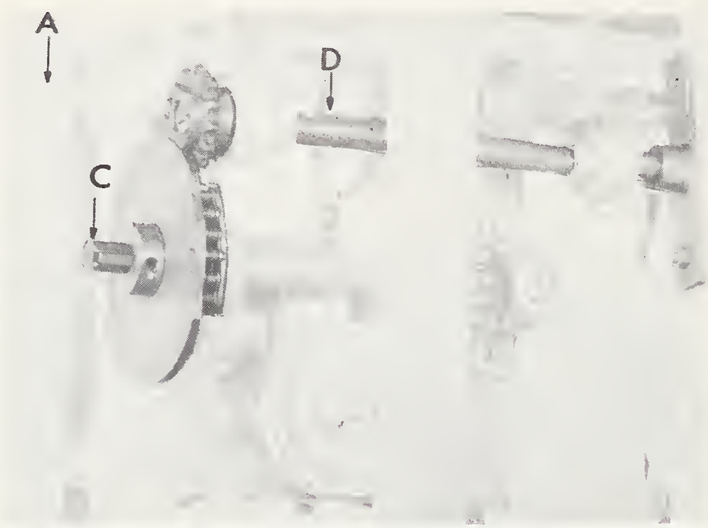

Figure 8. Intermittent gear on shaft C and mating gear (sprocket) on shaft D after plungers reach bottom of stroke. When the driving sector of the intermittent gear is disengaged from its mating sprocket (at either top or bottom of stroke) shaft D is prevented from turning by one of the concave sections on the projecting hub of its gear matching concentrically with the flange of the intermittent gear.

Rotating Knife and Gaging Mechanism for Transverse Cuts

The knife for transverse cutting is attached to a hub mounted on shaft B (Figs. 9, 10, and 11), which rotates continuously at an uniform velocity. This hub has an internal keyway that fits over a key fixed to shaft B. A sliding fit allows the hub to move vertically on the shaft. The gaging mechanism (Figs. 10 and 11) regulates the plane in which the knife is to rotate at the time the transverse cut is made. The first plunger forces the potato down through the knives in the table. The lower end of the tuber presses the gaging pad downward. The distance the gaging pad is depressed depends upon the length of the tuber. The linkage is such that the rotating knife is moved downward only one-half as far as the gaging pad. Thus the tuber is cut midway between its two ends if its length is no less than the distance between the pressure disk on the first plunger when at the bottom of its stroke and the gaging pad at its uppermost position. This distance can be adjusted to fit the range of sizes of tubers to be cut. Actual use has indicated that a setting of 3-1/4 inches between the pressure disk and the gaging pad will be suitable for almost all tubers of a size

suitable for cutting into six pieces. With this adjustment, any tuber within a size range from 3-1/4 to 6 inches long will be cut into pieces of uniform size. The stroke of the second plunger is the same (4-1/2 inches) as that of the first plunger but the relative positions of the two plungers are such that the second plunger has a lower downward thrust than the first one. The three prongs of the second plunger straddle the three blades of the fixed knife to push the upper one-half of the tuber down far enough to complete the longitudinal cutting.

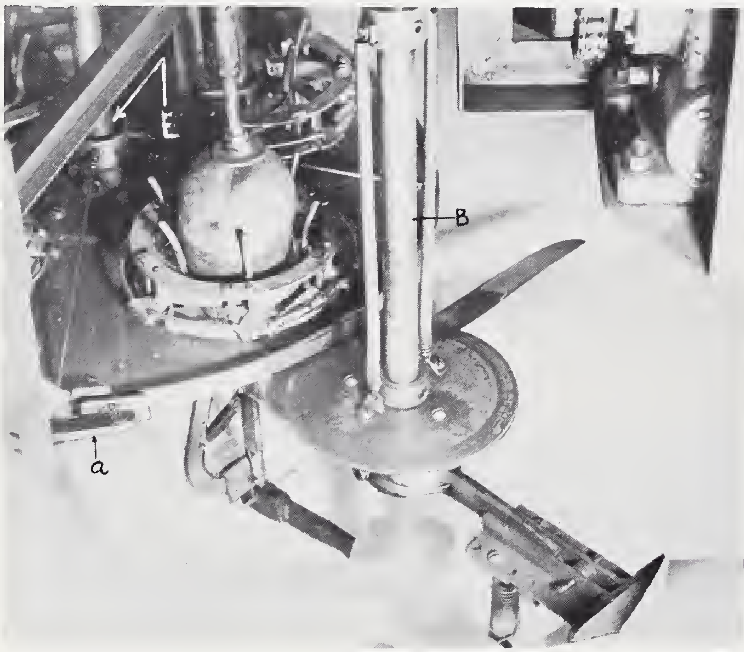

Figure 9. Rotating knife at same point of cycle shown in figure 6. Brake arm (a) presses friction block against rim of table.

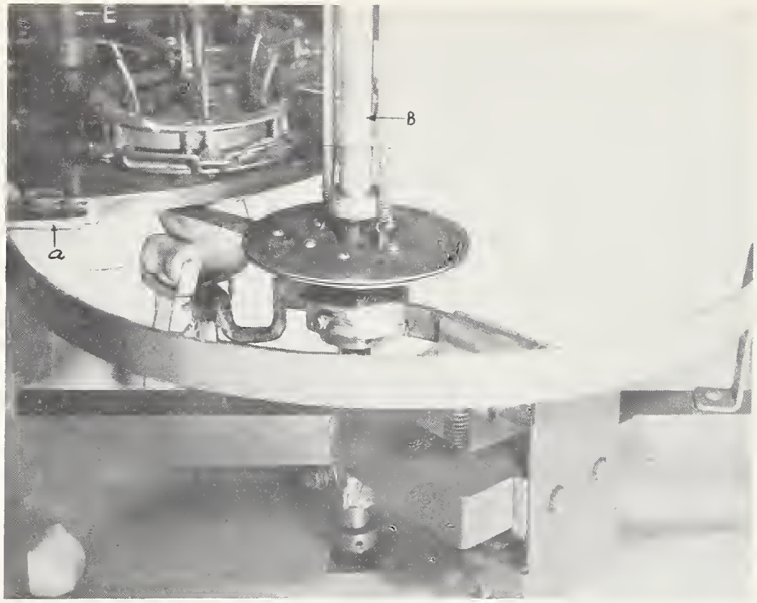

Figure 10. Transverse cut has just been completed. Note that knife mounting disk has been depressed by gaging mechanism, in this case three-quarters of an inch.

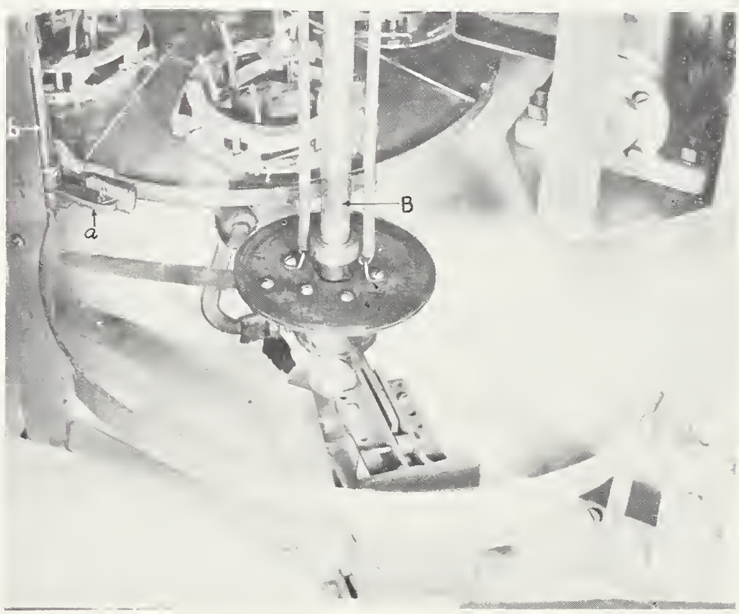

Figure 11. Plungers are ascending; brake (a) is released; and table is ready to revolve another 90°. The rod designated as (b) is a continuation of the part similarly designated in figure 5.

Synchronization of Motions of the Principal Functional Elements

Obviously it is necessary to have the action of the table, plungers, and rotating knife properly synchronized. Figure 12 shows the relative positions of these elements through one complete revolution for shafts B and D. The starting point, designated as 0°, occurs at the instant the

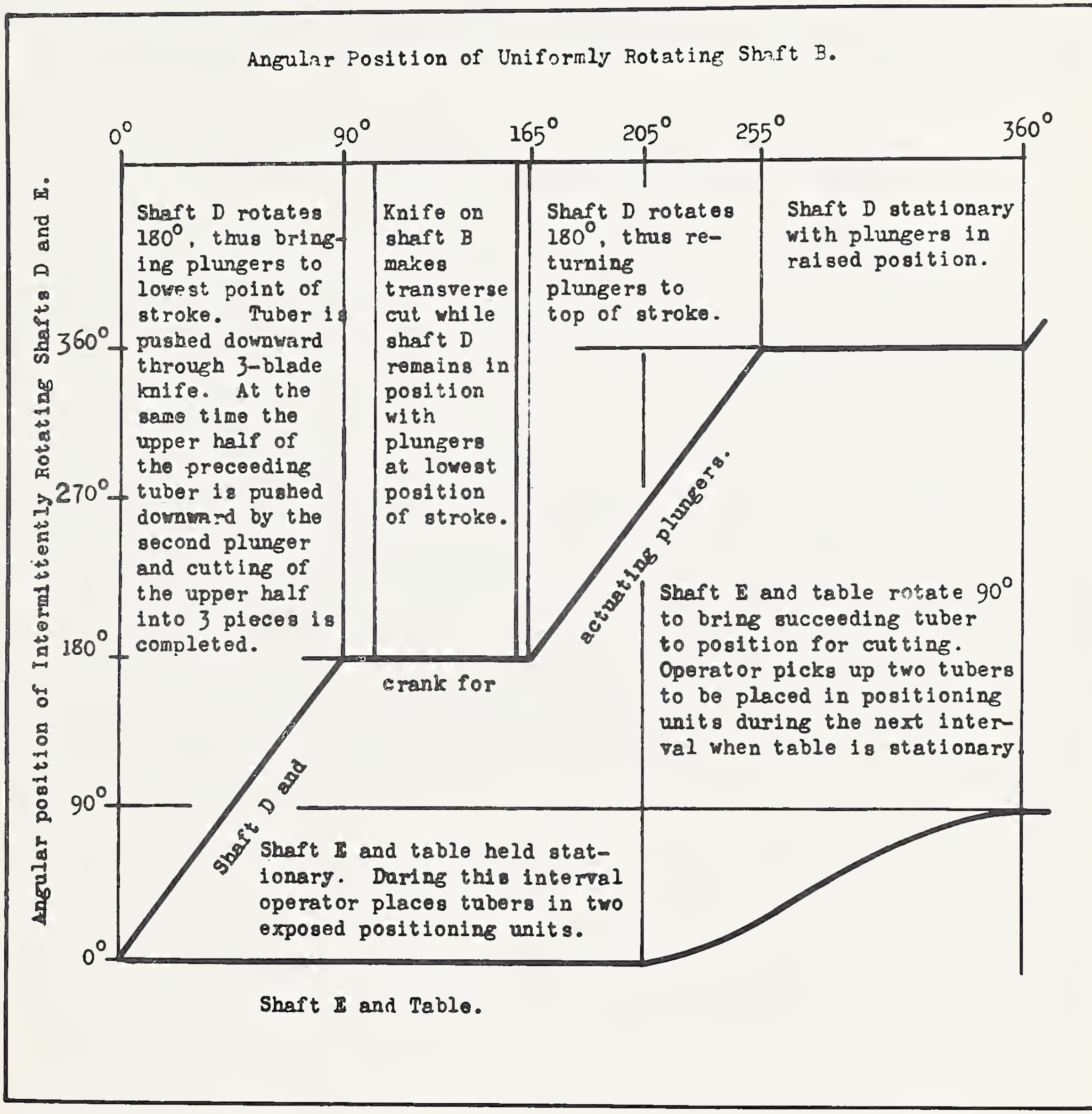

Figure 12. Synchronization of motions of plungers, continuously rotating knife, and table.

plungers start to descend. Shaft B, on which the knife for making the transverse cut is mounted, rotates without interruption at a uniform angular velocity. Shaft D, on which the plungers are mounted, turns intermittently but makes a complete revolution for each tuber cut. The table rotates 90° for each tuber. Each tuber is completely cut through vertically in two cycles. The shafts designated as B, D, and E in figure 12 are similarly designated in figures 3 to 11.

With machine speed regulated to cut 48 tubers per minute, the action illustrated by figure 12 would occur in an interval of 1-1/4 seconds.

DESIGN OF MACHINE BASED ON A RANGE OF TUBER SIZES DEEMED SUITABLE FOR CUTTING INTO SIX PIECES

The tuber size range selected for tubers to be cut into six pieces was from 7 to 13 ounces. Accordingly, individual tubers of three varieties of potatoes were weighed and measured. These varieties were Red Pontiac, Kennebec, and Irish Cobbler. Of those that weighed between 7 and 13 ounces, the lengths and widths were measured and recorded with the weights. Measurements were thus recorded for 198 Red Pontiac tubers, 45 Kennebecs, and 300 Cobblers.

Analysis of the data described above indicated the minimum and maximum tuber dimensions for which the machine should be designed. The minimum and maximum width found in the three varieties measured indicated that the tuber positioning-holding mechanism should be designed to accommodate tubers ranging from 2-1/2 to 3-7/8 inches in width. All of the 7- to 13-ounce tubers measured were in that range for width; nearly all up to 16 ounces were under 3-7/8 inches in width. The length in the 7- to 13-ounce range was found to vary from 3.0 to 5.8 inches. The length of the stroke of the plungers was based upon the range in lengths of tubers. The design of the experimental machine is such that tubers ranging in length from 3-1/4 to 6 inches, and in width from 2.5 to 4 inches can be satisfactorily cut into six pieces.

The A-section V-belt, by which the motor drives the input shaft of the speed reducer, is adjusted loosely as a safety measure in case too large a potato is inadvertently placed in the machine. The power required to drive the machine has not been measured. That the machine can be driven with a small motor sheave and a loose belt indicates that only a slight amount of power is required.

Uniformity of Seed Piece Size

The tuber positioning units (Figs. 3 and 4) and the gaging mechanism (Figs. 6, 7, and 8) for regulating the transverse cut are features intended to improve the degree of seed piece uniformity obtained. The lengths of the seed pieces from a given tuber are remarkably uniform in length. However, the irregular shapes of the tubers tend to produce a lack of uniformity in weight of seed pieces from given tubers.

To measure the degree of uniformity in weight of seed pieces, tubers were weighed before cutting. If one tuber is cut at a time, with the pieces that are produced being recovered before cutting the next tuber, there is no problem to associate the individual pieces with the original tuber and thus compare the actual weights of the individual pieces with the calculated weight of precisely uniform pieces. However, with this procedure the results may not be indicative of those obtained in actual operation as placement of the tubers is not continuous. To provide a degree of continuous operation in the testing procedure, tubers were weighed and segregated in different size categories. The tubers in one size category were then fed into the machine at a normal rate (48 tubers per minute) before the machine was stopped to collect the seed pieces. The weights of the individual seed pieces were recorded, but their identities with the original tubers were, of course, lost.

In one test, 50 tubers of the Red Pontiac variety were segregated by weights into 5 different size categories. All 10 tubers in each category were consecutively placed in positioning units with the machine running at a rate to cut 48 tubers per minute. The 60 seed pieces produced from each group were individually weighed. The grouping by weights are shown in figure 13. Had each tuber been cut into six pieces of exactly a single weight, the weights of all of the pieces would have fallen within the shaded portions of the bar graph. There were no pieces of less than one ounce in weight and no pieces exceeding by more than three-fourths ounce the maximum size that would have occurred had each tuber been divided into six pieces of equal weight.

If the 50 tubers in the 5 size groups are considered as a single group 84.2 percent of the total number (300) of pieces are within the weight range (1.25 to 2.5 ounces) that would include all of the pieces had each of the 50 tubers been divided into 6 pieces of equal weight. It is to be noted that 100 percent of the seed pieces produced weighed more than an ounce.

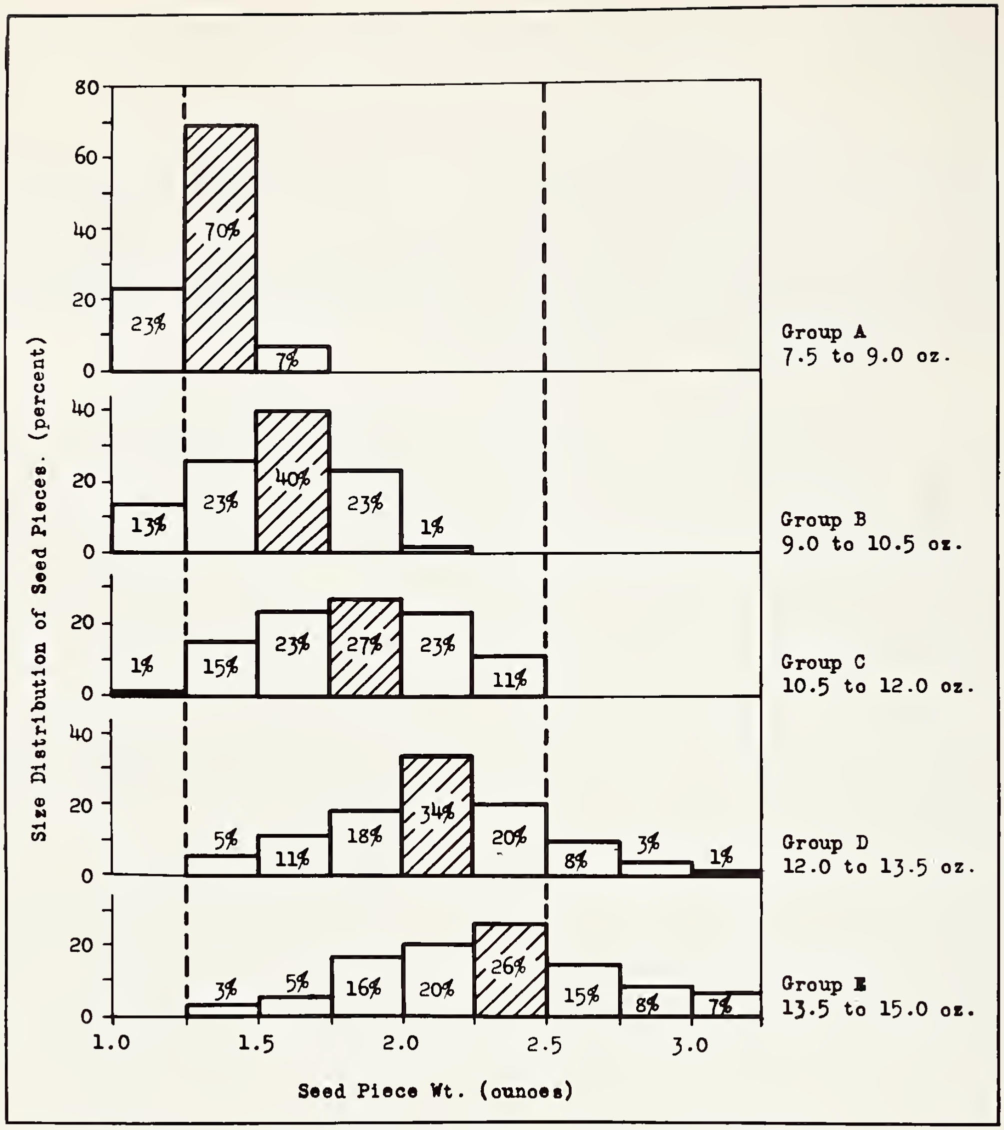

Figure 13. Test results of seed piece size distribution. The vertical broken lines indicate the limits within which all of the seed pieces would fall if each and every potato had been cut into pieces of equal weight.

Because this experimental machine was designed for a special purpose rather than as a substitute for existing commercial seed potato cutters, no tests were conducted to make comparisons between the experimental unit and commerical machines. Before this experimental machine was designed the performances of several commercial machines in operation were evaluated in respect to seed-piece-size uniformity. A characteristic of both the automatic and nonautomatic commercial machines is the production of a small percentage of excessively small seed pieces. All of them produce some pieces weighing less than one-half ounce. The proportion of less than one-half ounce seed pieces ranges from 1 to 9 percent of the total number of seed pieces.

Seed Cutting Capacity

The productivity possible with this machine is dependent upon the operator and the average size of the tubers. The machine speed can be readily changed. Operational tests at various speeds indicate that it is not difficult for the average worker to feed it continuously when the machine is operating at a rate of 48 cycles per minute. It appears that 60 cycles per minute is probably the maximum practical speed with a dexterous operator.

The number of seed pieces cut per hour is independent of the size of the tubers so the capacity of the machine is indicated, in table 1, by the number of seed pieces per hour as well as hundredweight of tubers cut per hour.

Table 1 shows the production if the operator places a tuber in each positioning unit as the table rotates. Over a period of time, such as an hour, there are likely to be a few misses and the actual production will be something less than the maximum possible at a given machine speed.

Table 1. Seed Cutting Capacity of Experimental Seed Potato Cutter

Tubers per minute	Seed Pieces per hour	Hundredweight of tubers cut per hour	
		Average seed piece 1-1/2 oz.	Average seed piece 1-3/4 oz.
48	17,280	16.2	18.9
52	18,720	17.5	20.5
56	20,160	18.9	22.0
60	21,600	20.2	23.6

Extended-Use Tests of Seed Potato Cutter

In 1959 and 1960 this experimental seed potato cutter was used by the Red River Valley Potato Growers Association to cut approximately 900 cwt. of seed potatoes.

A grower in North Dakota has had custom built for his own use two seed potato cutters similar to the experimental machine. In 1960 these machines were used to cut several thousand hundredweight of seed potatoes with apparent satisfaction.

SUMMARY

This seed potato cutter was primarily designed to cut into six pieces of uniform size and shape both long and round varieties of potatoes. Tests have demonstrated that the machine will do this successfully, producing desirable blocky shaped seed pieces. The machine is well suited for use with Red Pontiac and other varieties with sufficient eyes for cutting into six pieces.

The productivity of one worker using the experimental hand-fed seed potato cutter can equal the output of 4 or 5 average workers cutting seed potatoes by hand.

By removing the rotating knife the machine can be used to cut tubers into 3 pieces, and by substitution of suitable knives on the rotating table it could be used to cut tubers into either 2 or 4 pieces. These possibilities are only incidental to the manner in which the tubers are cut and was not regarded as a requirement in the design of the machine. Neither is it particularly important inasmuch as there are commercial seed potato cutters that can more efficiently cut tubers suitable for 2, 3, or 4 pieces.

ACKNOWLEDGMENT

A. J. Dubuque, Engineering Aid, ARS, was responsible for executing most of the machine tool work involved in construction of this experimental seed potato cutter. The writer is appreciative of the suggestions from Mr. Dubuque, which are incorporated in this experimental machine.

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